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Abstract

Simulation is the process of synthetically manipulating the variables in a model of a system for the purpose of understanding, experimenting with, and predicting the behavior of that system. Many different models are now being developed by university administrators to aid them in making decisions. Simulation models have been developed for predicting instructional programs, academic program structures and space utilization. Many of these models must wait for implementation until adequate information is collected which will allow meaningful values to be placed on the variables. At the present stage of development of the art, the more experimentation carried on in different kinds of institutions with different kinds of approaches, the greater the progress will be. As individuals develop, test, and publish their efforts, the trading and borrowing of ideas and methods should begin to shape a comprehensive and diversified technology. (TC)

Eighth Annual Forum of the Association for Institutional Research

San Francisco, May 8, 1968

SYNTHETIC OUTPUT BY SIMULATION

An Introductory Paper

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If we were to revert from "buzz" words to plain English synonyms, the title of this panel session might read, "Artificial Information by Pretending." Such a literal translation of the jargon could well be made by the uninitiated using a contemporary dictionary. Of course, that happy translation does not do full justice to the rich and subtle meanings that "Synthetic Output by Simulation" evokes in those who are aware of the powerful impact modern systems science is having on research of all kinds these days. On the other hand, the simpler interpretation may not be too far off the mark.

Simulation is a technique that is being applied to all kinds of research, from anthropology to zoology, from bureaucracy to urban land use, from aerospace systems to warehouse location. It is a particularly powerful tool in the hands of the engineers designing machines. Planners, management scientists, and economists have positively fallen in love with simulation in their search for ways to predict and control the development of complex organizational and social systems.

The purpose of this panel is to take note of some of the applications of simulation, modeling, and gaming to institutions of higher education. Our four panelists were selected to represent a diverse range of experimentation and application of simulation models to colleges and universities. By way of introduction I shall make some general remarks about the nature, uses, and problems of simulation models in higher education administration and planning.

In its most general sense, simulation is the <u>process</u> of synthetically manipulating the variables in a <u>model</u> of some physical, biological, or social <u>system</u> for the purpose of understanding, experimenting with, and predicting the behavior of the system.

With a reasonably satisfactory model of the system, simulation may be used to evaluate or predict the costs or consequences of possible changes in the system over time. Hence, its value as a planning technique.

However, when knowledge of the system is too inadequate to develop an acceptable model, simulation may be used as a research method to test a variety of hypothesized models. A range of synthetic values for unknown parameters may be exercised and compared with known characteristics to see which model seems best to explain the nature of the system.

One of the more fascinating and fruitful forms of simulation applied to complex social systems is gaming. War games and management games have developed to a high degree of sophistication, especially with the advent of the computer. An imaginary but realistic environment is given the players, acting as part of the system, who make decisions in response to information and learn the consequences of their decisions in relation to the goals they are expected to optimize. Training in organization and operations decision-making by simulation will become even more effective as shared-time, rapid response computer gaming is perfected in the next few years.

Gaming also is being increasingly used for controlled artificial experimentation with the behavior of players acting in competitive, stressful, or cooperative situations. The potential of this kind of simulation application for institutional research merits consideration, especially by those interested in organization behavior, the college culture, and decision theory.

Upon drawing the assignment last year to chair this panel, I set out with the intention of surveying the field to learn what people in institutional research are doing in the way of modeling and simulation. In no time at all it became apparent that literally hundreds of people in dozens of institutions and agencies are working on one kind or another simulation model of some aspect of higher education. The diversity of approaches and applications is so great that brief summarization of the state of the art would be impossible -- and perhaps fruitless. Finally, it became painfully obvious that most efforts have yet to bear fruit in the way of actual output that can be significantly useful in the institution's policy making and planning process.

There are many model designs in the advanced stage of development; most of these are nonoperational as yet because their users are unable to acquire the data needed to place meaningful values on the variables. (By "meaningful," I mean those values institutional officers can judge to be valid in relation to their real world experience.)

At present, the major benefit flowing out of these efforts to develop institutional simulation models is more orderly, organized thinking about the nature of colleges and universities. In most cases I have observed, the design of a model is immediately followed by the initiation of intensive efforts to construct comprehensive information systems. Since the development of information systems usually turns out to be a long, laborious task, the model may be put on the shelf until the desired data are developed.

The act of designing the model, however, usually has a major influence on determining the types and forms of information required. Furthermore, since many kinds of information demanded by the models are not being generated in institutional operations, model design tends to set the agenda for institutional research, clarifying the kinds of in-depth studies needed to fill information gaps.

As yet, however, very few simulation models are actually being used in the institutional decision making process in planning and resource allocation. There are several reasons for this state of affairs:

First, the lack of adequate data to establish a reasonable set of values for the parameters describing the relationships in the system inhibits the activation of the model as an aid to administrative decision making. Responsible administrators are naturally loathe to trust the "synthetic output" of a simulation model if the data put into the model are unreliable.

Secondly, the communication gap between the technicians who develop the model and the administrators who are likely to use it may be a serious problem. Either the technicians really don't understand the kinds of relationships and output that are relevant to the administrator, or the administrator--the English professor turned dean--does not comprehend the jargon, methods, or numbers the technician uses in explaining his handiwork. It may take a full generation before higher level academic administrators are sufficiently sophisticated to make use of the potential of simulation and at the same time understand its limitations.

Finally, a president, treasurer, or dean can hardly be expected to make much use of a model that is so complex that he can't understand it or so simplified that it doesn't tell him anything. We must look for the middle ground called for by Richard Cyert (1966) "where the model is complicated enough to deal with reality but not so complicated that it impedes our comprehension of this reality."

At the University of Rochester, we have boiled down our planning model of the instructional program to such simple elements that it no longer deserves the title of "simulation model." I am guilty of referring to it as simulation, but essentially it is merely a computational procedure for evaluating gross alternative future possibilities. Nevertheless, the simple version (which was described to last year's Forum) has been of major value in assessing the impact of alternative enrollment sizes and mixes and alternative academic policies on the University of Rochester's ten year financial requirements (Mason, 1967 and 1968).

In the meantime, we have turned our research effort to a much more specialized variety of modeling. Under a grant from the Esso Education Foundation, my associate, F.W. Arcuri, is using a sophisticated mathematical model of student-course interaction as a tool for comparing the academic program structures of different institutions. This work, which will be reported in the near future, shows great promise as a powerful research method for probing the effects of academic policies and practices on resource requirements.

Arcuri's work also has demonstrated to me -- a mathematical illiterate and cookbook statistician -- the great importance of higher level mathematical abstraction in using models for research. As a director of institutional research and planning, I have been immersed in the problems offeeding information, analysis, and projections into the real-world decision processes of the university in all its complexity. The promise of the computer's ability to handle this complexity was very appealing.

My tendency -- and I suspect that many of us -- was to try to conceptualize the university as a "total" system and to model it in the sense of isolating what seemed to be the most critical variables affecting the kinds of difficult decisions being faced. But I could not escape the desire to express these variables in terms of the concrete operating language of the institution. I could not resist trying to account for as many of the real-world constraints and idiosyncrasies as possible. In no time at all my intuitive conceptualization of the institutional system greatly exceeded manageability and comprehensibility. The conception was not a model of the system, but an attempt to grasp the entire institution in terms of students, faculty, staff, dollars, square feet, activities, class sizes, contact hours, automobiles, and so on through the whole vocabulary of real things with which we deal.

In Arcuri's project, although the data put into the model involve real students in real institutions requesting real courses, the real-world constraints operating on the scheduling-sectioning problem are reduced to abstracted representation. At this stage, the model deals with a logical inventory of time unit and room unit pairs. A principal objective of the model is to measure the effect of the complex interaction of demand activities in time on expected facilities utilization. The current output of the model is a set of measurements of the structure of an institution's academic program.

Starting with only two elements of real data -- the identity of the individual student and the identity of the course section -- the Arcuri model produces measures of student course loads, class size distributions, the degree of prescribed curriculum or lock-step course enrollment patterns, and a series of completely new measures reflecting the nature of the interaction of students and courses. The comparison of the quantitative characteristics of a number of institutions -- ten widely varying types so far -- provides the basis for inferences about the impact of variation of program structure on resource utilization.

Subsequently by adding categories describing the attributes of students and the attributes of courses, the Arcuri model can become the basis for simulating the process of students interacting with courses in relation to space and time resources.

The value of abstracting a complex problem to a much simplified mathematical model does not need to be demonstrated to those of you with better scientific and mathematical backgrounds than mine. I have related this adventure in some detail because I have observed that many institutions get entangled with massive complexity in attempting to develop planning models only to see their efforts break down, leading to considerable disenchantment.

This leads me to some final observations on the process of wheel reinvention, allegedly a common ailment of institutional research. In the first place, we are not dealing with anything as simple as the wheel, although I have noted a number of schematic diagrams of models represented by the hub, spokes, and rim analogy. Secondly, I have yet to see identical models arise from independent investigators. Although many have common characteristics reflecting the common denominators among institutions of higher education, every effort has a differing approach and emphasis. At this stage of development of the art, the more experimentation carried on in different kinds of institutions with different kinds of approaches, the greater progress will be. As individuals develop, test, and publish their efforts, the trading and borrowing of ideas and methods should begin to shape a comprehensive and diversified technology.

Risking offense by omitting the names of many significant contributors to this technology, I should like to mention the work of a few that are not represented on this panel. Of great importance, of course, is the work of Keeney, Koenig, and Zemach (1967) at Michigan State. Under their NSF grants, Koenig and associates applied the well-developed mathematics of engineering systems research to higher education and designed a highly sophisticated "state-space" model. Segments are now being programmed as data resources are developed, and a prototype model was reported and demonstrated at the Symposium on Operations Analysis of Education last November.

The work of Baughman and associates at Ohio State, Jedamus at Colorado, Matt Steele and his associates at the University of Miami, and the Esso projects at Duke and Emory Universities are among many that have been making fruitful progress with a variety of modeling applications to higher education.

Our four panelists were selected both to demonstrate the range of variety and the reality of accomplishment in the applications of simulation to higher education decision-making.

Bertrand L. Hansen, special assistant to the president and director of institutional research at the University of Toronto, represents an institution that not only has been a prolific producer of simulation models but also is a living demonstration of their effective use in university planning and resource allocation.

Collin Scarborough is a partner in Peat, Marwick, Livingston & Company of Boston, the firm that has developed what I consider to be a very successful computer model for simulating the programs and resource utilization of a prototype university over a ten year span. I have experienced this model using a remote rapid access terminal on a time-shared computer, and I found the gaming exercise that may be played on the model to be realistic and significant.

Robert Koski, planning officer of the University of Washington, Seattle, reports major progress on the development and testing of that institution's computer planning model and the management information system being developed to support it.

The concluding speaker on the panel was John E. Keller, director of Analytic Studies of the University of California. Mr. Keller spent ten years in program and systems analysis in the Department of Defense during the period in which the powerful tools of cost-benefit analysis were perfected as instruments of policy-formation. Since 1965 he has been working with substantial success on the adaptation of those techniques to Multiversity. His remarks included a review of the uses of cost-benefit analysis in the allocation of resources in higher education and a description of several of the models developed at the University of California. That work is represented in these Proceedings by a paper by ______________________________ describing the ______________________________ developed under Keller's direction.

The presentations of the four panelists demonstrated that significant progress is being made in the development of simulation modeling in higher education, but we are only on the threshold of the promised--or threatened--potential of systematic planning and analysis in the management of colleges and universities.

Within the next few years, the diverse experimentation now going on will begin to yield a great many well-tested techniques, and it also will have generated a substantial advancement of our knowledge of how colleges and universities work and, hence, how they may be more effectively governed.

Suggested Reading

Richard M. Cyert, "A Description and Evaluation of Some Firm Simulations," in Proceedings of the IBM Scientific Computing Symposium, Simulation, Models, and Gaming (White Plains, N.Y., IBM Data Processing Division, 1966), pp. 3-22. This entire volume is a wealth of papers of major significance in modeling and simulation.

M.G. Keeney, H.E. Koenig, R. Zemach, A Systems Approach to Higher Education, Final Report, Project C-396, National Science Foundation (East Lansing, Mich.: Division of Engineering Research, Michigan State University, March 27, 1967).

International Business Machines Corporation, Bibliography on Simulation (White Plains, N.Y.: IBM Technical Publications Department, 1966). Nearly 1000 KWIC-indexed entries of publications, 1960 through 1964, dealing with simulation.

Thomas R. Mason, "The Role of Institutional Research in Decision Making," The Instructional Process and Institutional Research, Proceedings of the Seventh Annual Forum of the Association for Institutional Research, 1967, pp. 29-40.

Thomas R. Mason, "A Basis for Program Planning in Higher Education," Quarterly of the Society for College and University Planners, Vol. 1, No. 3 (December, 1967), pp. 1-4.

U.S. Office of Education, National Center for Educational Statistics, Proceedings of the Symposium on Operations Analysis of Education, November 19-22, 1967 (forthcoming in July, 1968). Includes papers by Keller, Hitch, Judy, Koenig and Keeney, and others of significance to higher education models.